Small gains in power efficiency now, bigger gains tomorrow

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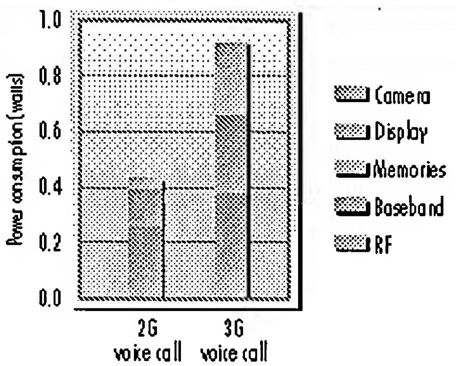
Consumers expect that advanced 2.5G and 3G cellular phones will come in the same form factors and exhibit the same battery life as existing 2G cellular phones. 2.5G and 3G "smart" phones offer users voice, data and multimedia capabilities such as mobile access to e-mail and personal information, robust Web-browsing capabilities, audio and video playback and streaming, and rich gaming. New cellular "smart" phones will use data services to enable new ways to communicate, access information, conduct business and learn.

But the added functionality and features of 3G cellular phones coupled with the requirement for backwards compatibility necessitates a tenfold increase in circuit complexity. This complexity in 2.5G and 3G handsets puts a strain on the power budget that can be relieved only by a top-down approach to power management coupled with advanced power-management devices and techniques. Unfortunately battery technology has not kept pace with increases in circuit technology. While digital electronics continues to double in capacity every 18 months as Moore's Law predicts, batteries are a relatively mature technology. Little increase in the energy density of nickel metal hydride (NiMH), lithium ion (Li-Ion), and nickel cadmium (NiCd) batteries is expected, and new technologies such as fuel cells are years away from commercial viability. Consequently, increased standby and talk times for cellular phones will result only from advances in circuit design if larger battery packs are to be avoided to preserve existing form factors.

The power consumption of a mobile handset can be compared to the fuel efficiency of an automobile. The automobile that we have today was not designed with fuel efficiency in mind. It can be slightly improved by advanced engine management or mechanical techniques, but automakers have had to completely redesign the

power train at the system level to realize dramatic improvements in fuel economy. Similarly, much of the circuitry found in a mobile handset was not designed with maximum power efficiency in mind. While the highly efficient and optimized power management of discrete voltage regulators can help the battery life of an advanced 3G handset, a top-down approach to examine the entire system will be necessary to further optimize the battery life.



In comparing 2G vs. 3G power consumption demands, increased services will take a higher toll on battery life in handsets. But there are power-management techniques available that can be used to promote voltage regulator efficiency in today's cell phones as well as system-level energy conservation methods that will be employed in the future.

Source: National Semiconductor

Top-down analyses of cellular phone power budgets reveal that the digital circuitry consumes about 35% of the total power in a cellular phone. Today's 2G cellular phones rely primarily on low-dropout regulators (LDOs) to supply the power for the various subsystems in the handset. This approach is proving impractical for 2.5G and 3G cellular phones because designers are realizing the digital circuitry in deeper and deeper sub-micron processes. For example, a baseband processor fabricated in a 0.13-micron process would require a nominal 1.3V supply. A single Li-Ion cell supplies a nominal 3.6V. However the actual supplied voltage can range from a fully charged 4.2V to a low of 2.7V, so significant voltage must be dropped across the LDO, resulting in an average conversion efficiency of only 36%.

Therefore, designers of 2.5G and 3G cellular phones are employing more efficient switching regulators for digital supply voltages. A well-designed switching regulator can reach conversion efficiencies well over 90%. Some synchronous step-down dc/dc converters are optimized for powering ultra-low voltage circuits, such as handset DSPs, from a single Li-Ion cell. These provide up to 400 mA with pin programmable output voltages to allow adjustment for baseband-processor voltage options without board redesign or external feedback resistors. Cell phone regulators often utilize a miniature chip-scale microSMD package to conserve space, and minimize the number of external capacitors required for filtering and voltage reservoir. For example, the LM2612 uses only two external capacitors - one 10-µF and one 22-µF - and one 10-µH inductor. And since portable devices spend significant time in low-power modes, a pulse frequency modulation (PFM) lowers the switching frequency to provide high efficiency conversion even under very light loads.

One paradox of low power operation is the switching regulator's need to supply current to the always-hungry central processor, even as it uses practically no current of its own. One device that will appear during the summer (the LM2608) substitutes a very low Iq (19µA typical) linear mode for PFM. That is, the device behaves like a switching regulator under high current load conditions, and a

linear regulator under light load conditions. This device provides up to 3 mA for deep sleep operation in advanced handsets. It offers a programmable output voltage set and can be mask-programmed at the factory for non-standard voltage sets.

Scaling voltages

If we use the automotive metaphor, there are several techniques for adjusting the power consumption of baseband processors and other handset power consumers. One possible scheme is adaptive voltage scaling.

Adaptive voltage scaling links the baseband processor and a switching regulator in a complete closed-loop system that dynamically adjusts the digital supply voltage to the minimum level needed for proper operation. Scaling the baseband processor's input voltage results in quadratic savings in power because the power dissipated by any digital VLSI circuit is proportional to the square of its input voltage. A handset implementing AVS in voice-mode, can reduce the baseband power dissipation by a factor of two over conventional circuit implementations.

There are other places in a cellular phone where switching regulators can be used in place of LDOs. For example, the transmitter power amplifier (PA) is a huge component of a cellular handset's power budget. Typical transmitter efficiencies are in the order of 30% to 40%, best case. A PA is optimized to have highest efficiency at maximum transmit power. Since most handsets operate relatively close to basestations, the handset radios reduce transmit power to the minimum needed to maintain quality communication. At the reduced power levels, the PA efficiency suffers. By employing adaptive voltage scaling and adjusting the power amplifier's voltage optimally, transmitter efficiency can be increased by 10% to 20%.

A device such as National's LM2614 allows active voltage scaling for the PA via a simple user application circuit. This circuit can be configured by the user to provide the desired control and transfer functions to position Vout for optimal PA efficiency. Like the LM2612 and its linear mode sibling the LM2608, its switching activity can be synchronized to an external clock. External compensation can be effected with two SMT components, allowing the switching regulator circuit to be tuned for the desired loop response regardless of the user's choice of operating frequency or output filter components. This device is the subject of intense design activity among 2.5G handset manufacturers.

Products optimized for use in WCDMA and other advanced applications are being released later this year. Featuring the same high efficiency, current mode architecture as the previous designs, they integrate the control circuitry required for active output voltage programming. In addition, they provide an integrated bypass FET for operation under end of battery life conditions and include design improvements intended to benefit system manufacturers. One such improvement is a precision trim for current limit, which allows the system designer to specify inductors within a closer tolerance than has typically been possible in the past.

By applying system-level energy conservation methodologies, a handset designer will be able to dramatically increase the usable life with a given battery size. Through careful application of high-

efficiency power conversion, closed-loop voltage optimization and the careful analysis of system energy losses, improvements of as much as 5 times in battery life are achievable.